Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE SATSOP FORMATION OF OREGON AND WASHINGTON

J HARLEN BRETZ
University of Chicago

The name "Satsop" was given by the writer[1] in 1915 to a deposit of stream gravels in the Chehalis valley of western Washington. The deposit was known then to extend throughout most of the length of this valley and to occur only in dissected terraces of stained and decayed gravel standing high above the valley floor. So far as then known, the Satsop formation rested unconformably on Eocene and Miocene marine sediments. Because of this relationship and because of its limitations as a valley filling, it was thought to be of Quaternary age.

Two field seasons have since been spent in the study of this formation in Washington and Oregon. It has been found in places along almost the entire Pacific coast line of Washington and along the Columbia River valley from the Pacific to the great lava plain east of the Cascade Range. It has been identified from the literature along the coast of Oregon. Its relations to the Coast Range and the Cascade Range are very different, and constitute the chief reason for the appearance of this paper.

The Satsop formation in the Chehalis valley.—The river gravels which constitute the Satsop formation of this valley exist along the lower 60 miles of its total length of 85 miles. The formation extends back up several tributary valleys, the type sections occurring in one of these, the Satsop valley. The maximum known thickness is 300 feet. The formation is composed of local materials and is stream-bedded with dip down the present drainage lines. Dissection has reduced the formation to a series of terraces, and decay has produced a residual loam on the surface of the highest terraces and given a dull red or orange color to the upper 50 feet of gravel.

---

[1] J H. Bretz, "Pleistocene of Western Washington," *Bull. Geol. Soc. Am.*, XXVI (1915), 131.

The Satsop formation along the Pacific Coast of Washington.—The terrace gravels which constitute the Satsop formation of the Chehalis valley are traceable almost continuously in the cliffs along the lower part of this valley and in the bluffs of Grays Harbor to the sea-cliffs of the narrow coastal plain.

North of Grays Harbor the formation differs from that in the Chehalis valley only in containing much clay and sand, with fragments of driftwood. In places there are strata of peat or lignite several feet thick. The gravel in some exposures is a beach shingle and lies on wave-worn and mollusk-drilled Tertiary sandstone. The formation is horizontal for the most part, and such warping as does exist is very slight. The formation rests unconformably on Tertiary and older rocks. A few marine shells record the presence of the sea, and the interbedded peat tells of tidal marsh conditions in places during accumulation of the deposit. The thickness of the formation as shown in the cliff sections does not exceed 200 feet.

The shore line of Willapa Bay, south of Grays Harbor, is largely cliffed, and all of the cliffs are cut in the Satsop formation. Clay and sand predominate. Peaty strata record the presence of fresh- or brackish-water swamps during aggradation. Shells of marine mollusks, cross-bedding due to tidal currents, and beach shingle in the gravelly strata tell of deposition in marine water. One stratum of highly fossiliferous clay is traceable for several miles along the bluffs. Most of the shells in it are of oysters, many of the valves yet attached in pairs. The shell-bearing stratum rests on blue clay, which is full of molluskan borings but contains no shells. Above the shell bed is a peaty clay containing much driftwood. Stumps *in situ* and upright stems in this layer record succession of the oyster bed by a coastal marsh. In the gravelly strata are pebbles of granite, gneiss, schist, and quartzite, all but the quartzite considerably decayed. None of these materials occur in the drainage area of either the Chehalis or the Willapa River, while all of them are common in the Satsop formation of the Columbia valley. This gravel undoubtedly was brought over into the Willapa Bay region by distributaries of the Columbia during the Satsop aggradation.

The Satsop formation in the Willapa Bay region is a little more than 75 feet in maximum exposed thickness, with the base below tide. The strata are horizontal or depart from that attitude only in gentle undulations.

The formation may be traced back up the Willapa valley into terraces of a decayed and red-stained river gravel which rests on eroded Eocene basalt and Miocene sandstone. The relation between the coastal and valley phases in the Willapa valley is the same as that in the Chehalis valley.

The Satsop formation along the coast of Oregon.—J. S. Diller[1] has described Quaternary sediments along the Oregon coast which belong clearly to the same formation as those along the coast of Washington. Diller did not name this formation and it has subsequently received but passing mention in the literature. Hence the name "Satsop" is here extended to cover that Quaternary formation of the Pacific Coast whose minimum limits reach from the Strait of Juan de Fuca north of Washington to the Coquille valley, within 80 miles of the Oregon-California line.

Exposures of the Satsop formation examined by Diller are as follows:

Ilwaco, Washington: 14 feet of gravel, sand, and clay, the top lying 30 feet above tide. Contains fresh shells of living species of mollusks. Unconformable on tilted shales of Oligocene age.

Tillamook Bay, Oregon: 20 feet of sandstone, capping a bluff of basalt 300 feet high.

Yaquina Bay, Oregon: Nye Beach: 40 feet of horizontally bedded gray sand overlying 20 feet of tilted Miocene shales. Sand contains logs, branches, and roots, some roots apparently *in situ*. Another section: 10 feet of yellow sand overlain by 5 feet of indurated gravel, this overlain by 6 feet of sand. Another section: 30 feet of Quaternary materials containing cones identified by F. H. Knowlton as of tideland spruce.

---

[1] J. S. Diller, "A Geological Reconnaissance in Northwestern Oregon," *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, 1896.

Newport Point: Sand and gravel unconformable on Miocene shales. Clay contains a multitude of marine shells, identified by Dall as belonging to six living genera. Wood and cones also present.

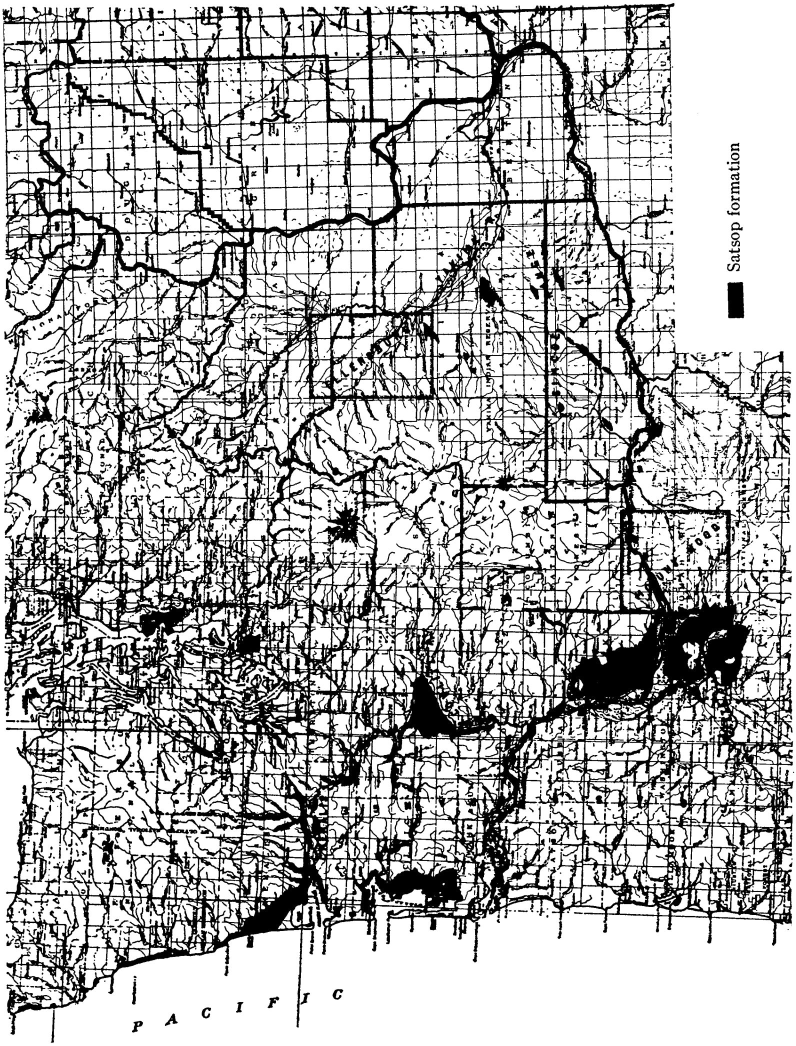

FIG. 1

Coquille valley: 30 feet of sand, summit 50 feet A.T.

The Satsop formation in the Columbia valley west of the Cascade Range.—The Satsop formation in the lower Columbia valley does not differ in any essential from that in the Chehalis and Willapa valleys. It contains a surprisingly large amount of quartzite gravel. In some strata more than 50 per cent of the pebbles are of quartzite, all of which undoubtedly have come from east of the Cascade Range. Basalt, a common country rock, is also a leading constituent of the gravel. The basalt pebbles are decayed, except in the deeper portions of the deposit.

There are three large areas in the drainage of the lower Columbia where the Satsop formation covers many square miles, instead of being limited to narrow terraces. One of these areas is in the valley of the Cowlitz River, a tributary of the Columbia from the north; a second is in the valley of the Willamette River, a tributary from the south; and a third lies in a broad portion of the Columbia valley between the two areas just mentioned.

The Satsop formation in the Cowlitz valley is at least 150 feet thick. It here constitutes a broad, terraced plain and rises northward to a summit level tract about 500 feet A.T. This tract is a portion of the divide between the Cowlitz and Chehalis rivers. It bears a residual soil and with little doubt is part of the original upper surface of the formation. The pebbles in the upper 30–50 feet are softened by decay, those immediately below the soil being spaded through in excavating. At depths greater than 50 feet the pebbles are hard, but the reddish to yellowish stain penetrates as far as excavations have gone. No quartzite pebbles have been found in this part of the Satsop formation. The dissection of the tract is adjusted to a base-level recorded by a broad terrace 100 to 150 feet lower than the summit plain and about 250 feet above the present flood plain of the Cowlitz River. This terrace has been found in most of the major valleys of the region studied. From its notable development in the Cowlitz valley it is here named the Cowlitz Terrace.

Only the lower 25 miles of the Willamette valley of Oregon have been examined in the study of the Satsop formation. Most of this portion is covered by the Satsop. Numerous hills of basalt rise through and several hundred feet above the surface of the Satsop fill. The formation is at least 600 feet thick along the Sandy River, with the base below river-level. The material is stream-bedded gravel and sand, indurated in some places to a conglomerate and sandstone. Quartzite is a common constituent for 10 miles south of the Columbia, but has not been found more than 15 miles from the master-stream. Quartzite and basalt are the most important constituents.

The Satsop formation of the lower Willamette valley is maturely dissected, the dissection adjusted to a base-level 200 feet or more above present flood plains. This level is recorded in the major valleys by a prominent terrace developed mostly in the Satsop formation but in places cut in the underlying basalt. This is the Cowlitz Terrace already described.

The uplands of this Satsop plain bear a red clay soil 10–15 feet deep. This grades down into a much-decomposed gravel. At a depth of 30 feet the pebbles are decayed only on the exterior. Below 50 feet most of the material is hard and ringing when struck with the hammer. Near the Columbia the clayey residual soil on the top of the Satsop formation contains scattered quartzite pebbles, hard, bright, polished, and apparently unaffected by the weathering which has reduced the associated basaltic pebbles to a structureless clay.

The surface of the Satsop formation in the Willamette valley lies at about 500 feet A.T. in mid-valley and rises eastward toward the Cascade Range to 1,200–1,500 feet, at these altitudes passing under the more recent lava-flows of this range. No upward slope of the Satsop surface toward the Coast Range on the western side of the Willamette valley has been found. On this side the formation terminates against hills of older basalt.

The broadened portion of the Columbia valley between the Cowlitz and the Willamette is really a continuation of the Willamette valley northward into Washington. The surface of the Satsop formation constitutes at least 200 square miles of the flat floor of this part of the valley. It is disposed in two levels, approximately 300 and 500 feet A.T., the lower of which is the Cowlitz

Terrace and the upper probably the original surface of the formation. This filling is very similar in all features noted in the preceding description to that in the Willamette valley.

Relation of the Satsop formation to the Coast Range of Oregon and Washington.—The Chehalis and Columbia rivers cross the Coast Range in capacious valleys of low gradient. In both valleys the Satsop formation has been found at closely spaced intervals from the coastal plain portion to the broad fillings east of the range. Though not continuous across the range, the character of the material of the formation, the altitudes at which it occurs, the stratigraphic relations to underlying rock and to younger gravels, and the topographic relations are such that there seems no reasonable doubt that the deposits noted in this paper are portions of the same formation.

The Cowlitz, Chehalis, Columbia, and Willamette valleys are younger than the Coast Range, and the Satsop formation is younger than the valleys in which it lies. Thus the Satsop formation was deposited after the Coast Range had been uplifted, and after its dissection was well advanced toward present maturity.

The Satsop formation along the Columbia River in the Cascade Range.—The Columbia has cut its valley across the Cascade Range down almost to sea-level. This valley is a gorge about 60 miles in length, only the western 35 miles of which have been mapped topographically. Most of the walls of the gorge are precipitous and maximum sections of 4,000 feet are available.

Numerous bluffs along the lower 12 miles of the Oregon side of the Columbia Gorge reveal a flow of gray basalt, 25–100 feet thick, in the Satsop formation. The Satsop rises northeastward in the walls of the gorge about 90 feet to the mile, bringing its base 900 feet A.T. in the salient known as Angels Rest (Fort Rock) and exposing the Columbia River lava below the Satsop. Many sections along this distance show an unconformable contact between the Satsop and the underlying basalt, and some of them show the upper 10–20 feet of this basalt to be very much decayed, far exceeding the decay of the basaltic pebbles in the lower part of the Satsop. In the section at Angels Rest the Satsop (including the intraformational lava) is 500 feet thick. A second lava-flow appears in this section, capping the Satsop gravel and constituting the surface formation back from the edge of the Columbia Gorge. It may be traced along the cliffs to a volcanic cone known as Devils Rest, overlooking the gorge but a little back from the bluffs. Devils Rest is one of a dozen or more such cones near the gorge which have supplied the lavas overlying the Satsop formation.

The accompanying section (Fig. 2) tells the rest of the story better than would a detailed description. The intra-Satsop flow does not appear elsewhere in the range, but volcanic fragmental material is prominent in most sections of the formation. All phases of this material are present, from ash and lapilli to volcanic bombs, rudely stratified by their fall; from slightly water-rolled and poorly sorted dêbris to well-worn pebbles and cobbles of the gray lava, associated with equally worn pebbles of Columbia River lava and beautifully smoothed and polished pebbles of quartzite.

The Satsop deposit invariably rests on eroded Columbia River lava (a dense black basalt) and is capped by flows of gray basalt. In places the Satsop is absent and the two lava formations are in contact. The highest altitude at which the Satsop formation has been found in the Cascade Range is 3,700 feet A.T. in Benson Plateau midway across the range. Its thickness here is nearly 700 feet.

On the eastern slope of the main range the river phase of the Satsop (i.e., well-stratified gravel composed predominantly of basalt and quartzite) appears at 2,500 feet and descends eastward to 100 feet A.T. in the synclinal Hood River valley. The formation in this is

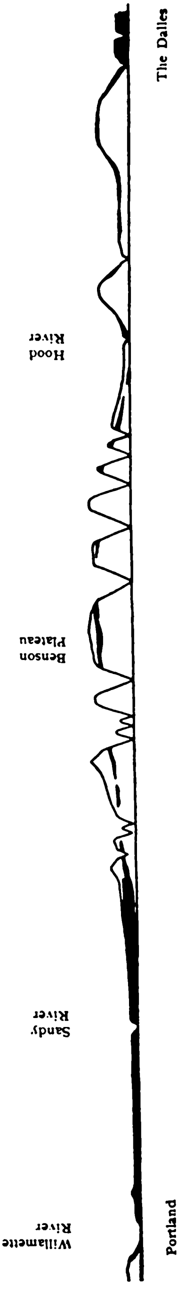

FIG. 2.—The Columbia River section of the Cascade Range. Oregon side. Looking north. Satsop formation shown in black

strikingly like that along the Sandy River, just west of the range. This is true of its composition, its structure, its degree of weathering and of cementation. It differs in having no lava-flow within the formation.

Between Hood River and The Dalles, the Columbia River has cut across two anticlinal ridges, each rising more than 2,000 feet above the stream. Each anticline is composed almost wholly of Columbia River lava. Each carries patches of a sedimentary formation composed chiefly of volcanic detritus, but containing much rounded gravel in which basalt, granite, and quartzite are present.

In the vicinity of The Dalles is a stratified deposit of volcanic agglomerate, tuff and ash, with strata of river sand and gravel, 1,000 feet thick, and capped by a flow of gray basalt. The western margin of the deposit is uptilted on the flank of the eastern anticline. Though no pebbles of quartzite or granite were found during the brief examination possible, it seems probable from stratigraphic evidence that the deposit at The Dalles is a local phase of the Satsop formation.

The Satsop formation between the Columbia and Yakima valleys.—The Simcoe Range is a prominent eastward spur of the Cascades, extending some 50 miles east of The Dalles, and separating the lower Yakima valley from the Columbia valley to the south. The range is structurally a broad anticlinal fold. Typical Satsop quartzite gravels, resting on dense black basalt and covered by gray basalt, lie in many places on the southern slope. The highest altitudes at which these gravels are known to occur in the Simcoe Range is 4,000 feet. The overlying lava does not extend far down the northern slope of the range, and the Satsop formation on this slope, unprotected by a lava cap, consists only of scattered quartzite cobbles and pebbles. All other materials in the original deposit have been destroyed by weathering. Quartzite pebbles were found as far north of the range as the southern part of the Ellensburg quadrangle. There are areas within sight of the Yakima River where these pebbles cover 50 per cent or more of the surface.

The Yakima basalt in the Ellensburg quadrangle (probably the equivalent of the Columbia River lava) is overlain by the Ellensburg formation, largely a sandstone of volcanic débris. Both the Yakima and Ellensburg formations have been folded into a number of east-west anticlinal ridges. Ahtanum Ridge is one of these folds in the southern part of the Ellensburg quadrangle. On this ridge the quartzite pebbles lie on the eroded edges of both the Yakima basalt and the Ellensburg sandstone. Toppenish Ridge, between the Ahtanum and Simcoe anticlines, is similarly oriented, of similar origin, and bears abundant quartzite gravel on the edges of both formations.

Relation of the Satsop formation to the Cascade Range.—It is obvious from data already presented that the outpouring of gray basalt immediately succeeded, and in part was contemporaneous with, the deposition of the Satsop formation in the Cascade Range. From the position of the Satsop formation in these mountains, it is also clear that it and the overlying lava-flows were deposited before the Cascade Range was formed.

Relation of the Satsop formation to the Methow peneplain.—Russell first advanced the hypothesis that the accordant summit levels of the Cascade Mountains in central and northern Washington record a warped and dissected peneplain. Willis and Smith[1] have named this the Methow peneplain. They have identified it on the eastern slopes of the Cascades from Lake Chelan on the north to the Yakima valley on the south. In the Ellensburg quadrangle the Methow pleneplain is thought to truncate the Ellensburg sandstone and the underlying Yakima basalt. As interpreted by Smith, these formations were gently folded before the peneplanation. Development of the peneplain brought the surface of these folds down to base-level. Renewed folding along the same axial lines is thought to have followed the truncation so that the Methow peneplain is now a warped surface lying on the tops and flanks of the anticlinal ridges.

The significant item here contributed is that the mantle of Satsop quartzite pebbles lies unconformably on the tops and flanks of at least some of these anticlinal ridges. If they constituted a stratified deposit across the eroded edges of the underlying formations, the case for planation between two epochs of folding would be complete. However, the position of the mantle of loose pebbles is so strikingly similar to that of the stratified Satsop on the southern flank of the Simcoe Range and throughout the Cascade Range that ittle hesitation is felt in correlating the eroded surface named the "Methow peneplain" with the eroded surface beneath the Satsop formation in the Cascade Range.

---

[1] Bailey Willis and George Otis Smith, *U.S. Geol. Surv., Prof. Paper 19*, 1903.

But this eroded surface as exposed in the Columbia Gorge is irregular and numerous elevations in it rise several hundred feet above the base of the Satsop. This is well shown in the Willamette valley and the Hood River valley where these hills of basalt rise through the Satsop formation and the younger lavas. The surface on which the Satsop rests in the sections of the Columbia Gorge may be post-maturely eroded, but it is not a peneplain.

Further, it has been shown in this paper that the Coast Range rises above the Satsop formation in the Chehalis, Willapa, Willamette, and lower Columbia valleys and therefore was not a peneplain at the time of Satsop deposition.

The age of the Satsop formation.—Diller[1] reports that W. H. Dall found all of the species in a collection of shells from the Quaternary deposits on Yaquina Bay, Oregon, to be living forms. He also states that F. A. Lucas identified a large tooth from the same beds as that of a Pleistocene mastodon and that F. H. Knowlton identified cones from this formation as those of "*Picea stichensis* Carr.," the tideland spruce growing along this coast today.

In another paper[2] Diller has described deposits between Cape Blanco and Elk River, Oregon, about 50 miles north of the California line, which he names "Elk River beds." Dall states that the fossils collected from these beds are probably Pleistocene in age. Martin[3] has more recently examined the Cape Blanco region and reports two faunal horizons in the Elk River beds, the upper of which is very closely related to the Upper San Pedro series and "is at least Pleistocene in age" and the lower of which probably is very late Pliocene. The Elk River beds overlie the Empire beds with angular unconformity. Ralph Arnold and B. L. Clark[1] consider that the fauna of the Empire beds is "of very nearly the same age as that of the Purisima formation in the Santa Cruz Mountains of California, which is Pliocene, and not the oldest Pliocene" (Clark). 'The Elk River beds are apparently the same as the deposits of the Oregon coast farther north, which Diller called Quaternary.

---

[1] J. S. Diller, "A Geological Reconnaissance in Northwestern Oregon," *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, 1896.

[2] J. S. Diller, "The Topographic Development of the Klamath Mountains," *U.S. Geol. Surv., Bull. 196*, 1902, p. 30.

[3] Bruce Martin, "The Pliocene of Middle and Northern California," *Univ. of Cal. Publications, Bull. Dept. Geol.*, IX, No. 15 (1916).

Ralph Arnold,[2] in a description of the geology of the coast of the Olympic Peninsula of Washington, maps and names what is here called the Satsop formation as "Pleistocene gravel, sand, and clay." He notes the presence of tilted Pliocene beds (his Quinault formation), bearing a fauna similar to that of the Purisima formation of California. On these beds the Satsop formation rests with angular unconformity. B. L. Clark[3] believes that present knowledge of the Pliocene faunas of the Pacific Coast upholds Arnold's determination and that the scarcity of extinct species suggests strongly that the fauna is rather late Pliocene in age, though not the latest Pliocene.

Harold Hannibal,[4] in a paper by Ralph Arnold and himself, notes the Quaternary age of the oyster-shell bed in the Satsop formation of the Willapa Bay region.

Diller also collected fossil shells from shales 700 A.T. on the slopes of the Columbia valley 35 miles from the coast. Dall refers the shells to the Pliocene. The Satsop here is a terrace gravel down in the valley and younger than the Pliocene beds.

A clay stratum with abundant fossil leaves has been found in the Satsop formation on the western slope of the Cascade Range. Knowlton has examined collections from this bed and is of the opinion that the flora is Quaternary in age. He finds leaves of

---

[1] Personal communication.

[2] Ralph Arnold, "A Geological Reconnaissance of the Coast of the Olympic Peninsula, Washington," *Bull. Geol. Soc. Am.*, XVII (1906), 451.

[3] Personal communication.

[4] Arnold and Hannibal, "The Marine Tertiary Stratigraphy of the North Pacific Coast of America," *Proc. Am. Philos. Soc.*, 1913.

Quercus venustula and *Sequoia sempervirens* in the collection. Both are living species.

Age of the Cascade Mountains.—If the foregoing determinations are correct, the Cascade Range, at least in this portion, is of Quaternary age.

Acknowledgments.—During the progress of the field work on which this paper is based, nine weeks were spent with the Washington Geological Survey and four weeks with the Oregon Bureau of Mines and Geology. I wish to acknowledge indebtedness to both organizations, and in particular to Mr. Ira A. Williams, with whom I was associated during the work for the Oregon Bureau.